

# Designing User-Friendly Handouts for Mechanics Courses

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by

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**Abstract:** Supplemental lecture handouts in a mechanics class serve two purposes: they provide context (practical examples of the theory in the textbook), and they explain how to solve multiple step problems. In each case, the handout contributes something not available in the textbook. Good contextual handouts grab the attention of the reader by telling a good story, complemented by a meaningful graphic. Problem-solving handouts help students understand the sequence of steps required to solve a complex problem. Step-by-step instructions are accompanied by a step-by-step graphical sequence, like a series of movie frames. Each diagram includes a shadow of the previous diagram, so the student can understand the sequence better.

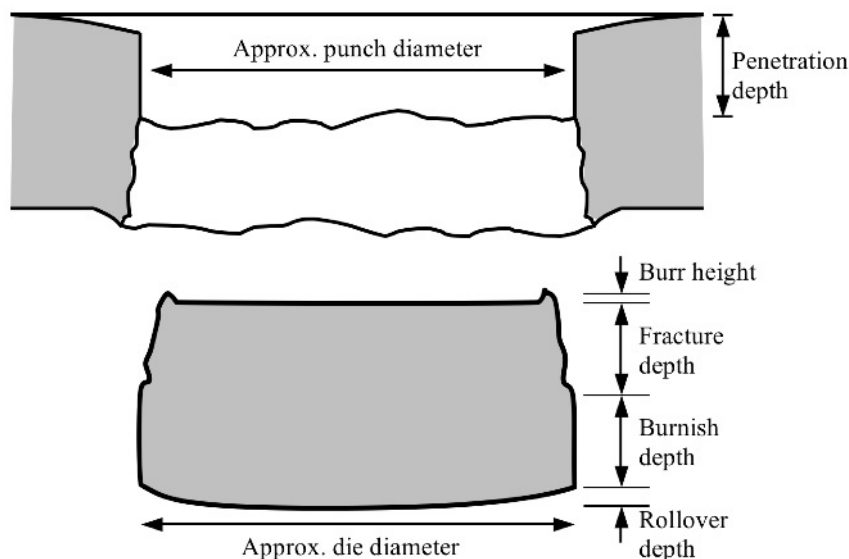
## I. Introduction

When I started teaching Strength of Materials to Mechanical Engineering Technology students, I discovered two challenges: first, students had difficulty relating theory to practice, especially traditional-age students.

Second, students had difficulty solving multiple-step problems. For example, although students could easily solve five independent problems requiring single-step solutions, they were rarely able to solve a single five-step problem correctly.

Like most of my colleagues, I approached the first challenge by discussing examples from my experience as an automotive engineer, and by bringing show-and-tell examples to class. Some examples were difficult to describe orally, or impossible to bring to the classroom as a show-and-tell (such as a collapsed building), so I created handouts to describe the application. Since the students were in the Mechanical Engineering Technology program, most handouts focused on machines and manufacturing processes. For example, one homework problem in Strength of Materials asks for the force required to punch a hole in sheet steel, using the ultimate shear strength, hole circumference, and sheet metal thickness. The handout which accompanied this topic helps students understand the complexity and richness of sheet metal punching, as shown in Figure 1. The footnoted reference for the data provides students with a source for further reading.

Sheet metal deforms, then fractures during blanking. Curvature and angles are exaggerated in these sketches of the sheared edges of a blank.



The depth to which the punch penetrates the sheet metal prior to fracture depends on composition, heat treatment, shear strength, and the degree of cold work.

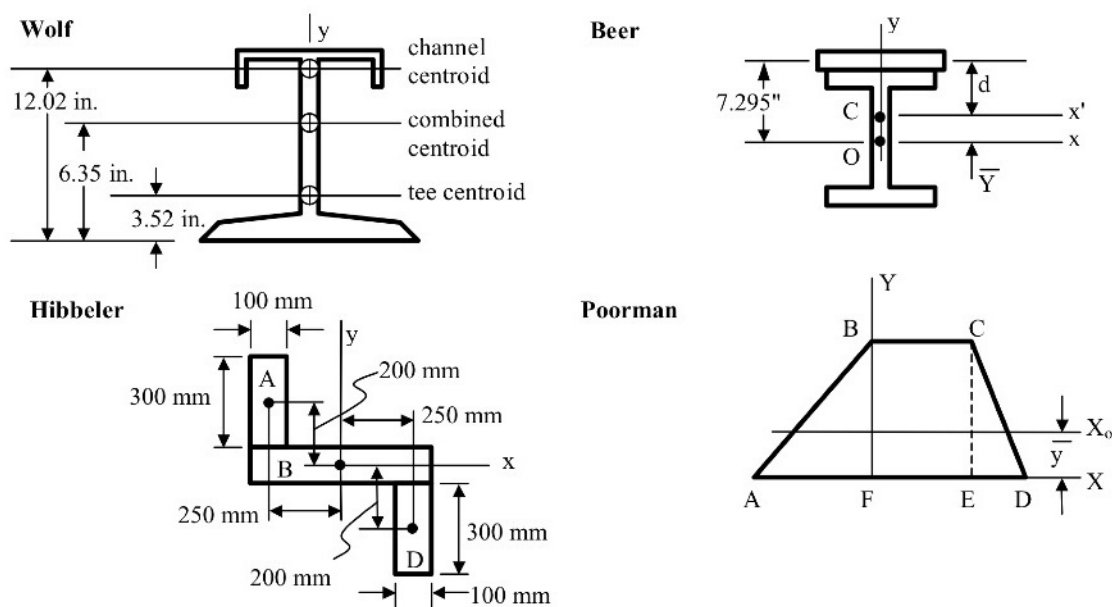
Metal	Penetration (%)	Shear Strength (ksi)
Steel, 0.10%C, annealed	50	35-43
Steel, 0.10%C, cold rolled	38	
Steel, 0.20%C, annealed	40	44-55
Steel, 0.20%C, cold rolled	28	
Steel, 0.30%C, annealed	33	52-67
Steel, 0.30%C, cold rolled	22	
Aluminum alloys	60	7-46
Copper	55	
Nickel alloys	55	35-116
Brass	50	
Zinc alloys	50	14-38
Silicon steels	30	
Bronze	25	

Ref. *ASM Handbook Vol. 14: Forming & Forging*, ASM International, 1988, p. 447, 448.

**Fig. 1:** Half-sheet handout on sheet metal punching theory and practice.

The second challenge, difficulty solving multiple-step problems, also lends itself to handouts. Students attend lectures, then complete homework problems outside of class. Students take notes on the problem-solving techniques in class, but most of the learning really occurs outside the classroom as students attempt to solve homework problems. Imagine yourself in a student's shoes: the assignment is due tomorrow morning, the professor

and your classmates have gone home, and you have three resources to rely upon for solving a multistep problem...the textbook, your notes from the lecture, and class handouts. The textbook describes a series of mathematical steps, typically accompanied by a diagram containing many construction lines, dimensions, and other quantities developed in the mathematical solution. For example, standard textbooks typically use a single diagram to illustrate how to calculate the moment of inertia of a complex shape, as shown in Figure 2.



**Fig. 2:** Recent textbooks by Wolf [1], Beer et al. [2], and Hibbeler [3] each use a single diagram to illustrate how to calculate the moment of inertia of a complex shape. This approach is not new; Poorman [4] used the same method in the 1940 edition of *Applied Mechanics*, originally published in 1917.

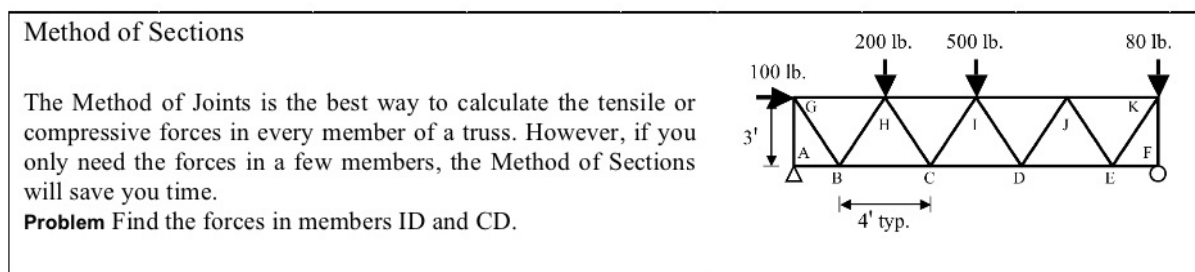
Now imagine you are reviewing your own notes from the lecture. They look a lot like the textbook: a series of equations accompanied by a single diagram. You created the diagram in several sequential steps, copying from the chalkboard during class, but only the finished diagram appears in your notes. The method for constructing the diagram is not evident from the finished product. When you try to solve a similar homework problem, neither the

textbook nor your notes are much help. What you need is a third path: a class handout to help you solve the multistep problem.

To fill this need, I created a series of step-by-step problem-solving handouts for Statics and Strength of Materials courses, covering topics such as beam design, truss analysis by the method of joints, truss analysis by the method of sections, frame analysis, and the calculation of the moment of inertia for a compound shape [5]. Each handout presents step-by-step solution methods in text and equations on the left, and graphics on the right. As the solution progresses, changes to the diagrams are emphasized at each step.

## II. Example #1: Method of Sections

The handout for solving truss problems uses six sequential diagrams to illustrate the Method of Sections. In the first frame, the initial dimensions and loads are shown. Accompanying text is shown at the left, while the diagram is shown at the right.



**Fig. 3:** The first frame of the Method of Sections handout introduces the problem in text and in a diagram.

The second frame helps the student calculate reaction forces at the two supports. The entire truss is treated as a solid block because reaction force calculations are independent of the geometry of the truss. To emphasize this concept, the entire truss is drawn as a solid block. This helps students avoid the misconception that individual truss members contribute to this part of the solution (a common error with my students). The dimensions shown on the diagram at the right are the dimensions used in the calculations at the left.

**Step 1** Calculate reaction forces at the supports, using three equations:  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$ . Treat the truss as a solid body, since reaction forces depend only on external forces and dimensions.

$$\Sigma M_A = 0 = -3\text{ft.}(100\text{lb.}) - 4\text{ft.}(200\text{lb.}) - 8\text{ft.}(500\text{lb.}) - 16\text{ft.}(80\text{lb.}) + 20\text{ft.}R_{Fy}$$

$$R_{Fy} = \frac{3\text{ft.}(100\text{lb.}) + 4\text{ft.}(200\text{lb.}) + 8\text{ft.}(500\text{lb.}) + 16\text{ft.}(80\text{lb.})}{16\text{ft.}} = 398.75\text{lb.}$$

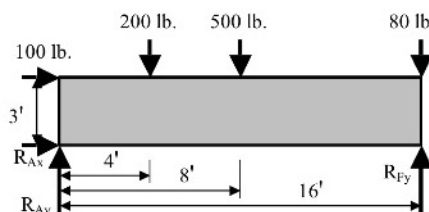
$$\Sigma F_y = 0 = R_{Ay} + R_{Fy} - 200\text{lb.} - 500\text{lb.} - 80\text{lb.}$$

$$R_{Ay} = -398.75\text{lb.} + 200\text{lb.} + 500\text{lb.} + 80\text{lb.} = 381.25\text{lb.}$$

$$\Sigma F_x = 0 = 100\text{lb.} + R_{Ax}$$

$$R_{Ax} = -100\text{lb.}$$

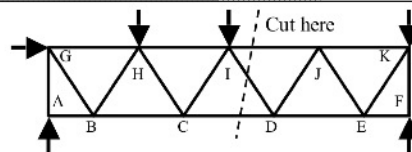
Since  $R_{Ax}$  is negative, the arrow is drawn backwards. Leave the arrow in this direction in all subsequent diagrams, and use the value of  $-100\text{lb.}$



**Fig. 4:** The second frame of the Method of Sections handout shows how to calculate reaction forces. Equations are listed on the left, interleaved with explanatory text.

The third diagram helps students figure out where to put the imaginary cut required by this method of solution. The truss geometry is relevant to this step in the solution, so it is shown. However, the cut is independent of dimensions and load values, therefore these numbers are not shown on the diagram.

**Step 2** Cut the truss. The cut must pass through a member you are solving for. The cut does not have to be vertical, or even straight, but it should pass through the fewest possible members. In this problem, a single cut passes through members ID and CD. In some problems, you may need to make more than one cut to calculate all the required forces.



**Fig. 5:** The third frame of the Method of Sections handout discusses the imaginary cut required by this solution method, and shows the location on a diagram.

The fourth diagram shows a free-body diagram of the cut truss, with arrows representing the longitudinal forces in the cut members. Again, since internal truss members do not contribute to this step of the solution, the cut truss section is shown as a solid block. The text explains sign conventions and how to perform the calculations. The fifth diagram illustrates how to use the ratio of the hypotenuse to the leg of a triangle, instead of using trigonometric

functions, to calculate horizontal and vertical components of force.

**Step 3** Draw one portion of the cut truss. Draw cut members as if they were external forces acting on the cut portion.

**Step 4** Use  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$  to calculate the forces in the cut members.

$$\Sigma M_I = 0 = 3\text{ft.}CD + 4\text{ft.}(200\text{lb.}) + 3\text{ft.}R_{Ax} - 8\text{ft.}R_{Ay}$$

$$CD = \frac{-4\text{ft.}(200\text{lb.}) - 3\text{ft.}(-100\text{lb.}) + 8\text{ft.}(381.25\text{lb.})}{3\text{ft.}} = 850\text{lb.}$$

CD is positive, so the arrow is drawn correctly. CD = 850lb. tension.

The vertical component of ID is  $(3/\sqrt{13})ID$ .

$$\Sigma F_y = 0 = R_{Ay} - 200\text{lb.} - 500\text{lb.} - (3/\sqrt{13})ID$$

$$ID = \frac{381.25\text{lb.} - 200\text{lb.} - 500\text{lb.}}{3/\sqrt{13}} = -383.09\text{lb.}$$

ID is negative, so the arrow is drawn backwards.  
ID = 383.09 lb. compression.

**Fig. 6:** The fourth frame of the Method of Sections handout shows how to calculate forces in the cut members.

The sixth diagram shows students how to reduce the complexity of a solution by selecting a different portion to analyze.

**Alternate Solution** Use the other portion of the cut truss. This solution looks simpler...instead of three applied loads and two reaction forces, there is only one applied load and one reaction force. Use  $\Sigma F_y=0$  to find ID, then use  $\Sigma M_J=0$  to find CD.

**Fig. 7:** The fifth frame of the Method of Sections handout shows an alternate solution.

These five Figures fit on one side of a single-sheet handout, which appears intact in the Appendix. Students are able to use the handout as a guide for solving truss problems on homework assignments and in open-book exams, using the Method of Sections. A two-sided single-sheet handout using the same layout design helps students solve truss problems using the Method of Joints.



### **III. Example #2: Frame Analysis**

The Method of Sections and Method of Joints handouts successfully helped students master these types of problems. Frame Analysis does not require as many distinct steps; in fact, there are only three steps. However, the second step may need to be repeated several times. The first diagram shows dimensions, pin locations, and externally applied loads. As in the Method of Sections, reaction forces are calculated by considering the entire frame as a monolithic solid. Therefore, the second diagram shows the frame in gray as if all members are welded together. Next, a free-body diagram of member D-E illustrates how to solve pin reaction forces.



### Frame Analysis

The object of Frame Analysis is to calculate the shear force on each pin. The solution takes three steps, although you may have to repeat the second step several times.

Only three equations are required:  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$ .

**Step 1** Calculate the external reactions on the frame *if possible*, using  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$ . Treat the entire frame as a single unit. In some cases, there are too many unknowns, and it is not possible to calculate all of the reactions.

In this frame, pin B is on a roller, so there is no horizontal reaction at B.

$$\Sigma F_x = 0 = R_{Ax}$$

$$\Sigma M_A = 0 = -500\text{N} \times 30\text{cm} + R_{By} \times 80\text{cm}$$

$$R_{By} = (500\text{N} \times 30\text{cm}) / 80\text{cm} = 187\frac{1}{2}\text{N}$$

$$\Sigma F_y = 0 = R_{Ay} + R_{By} - 500\text{N}$$

$$R_{Ay} = -R_{By} + 500\text{N} = -187\frac{1}{2}\text{N} + 500\text{N} = 312\frac{1}{2}\text{N}$$

**Step 2** Analyze each frame member separately. Calculate the pin reactions using  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$ .

$$\Sigma F_x = 0 = D_x - E_x$$

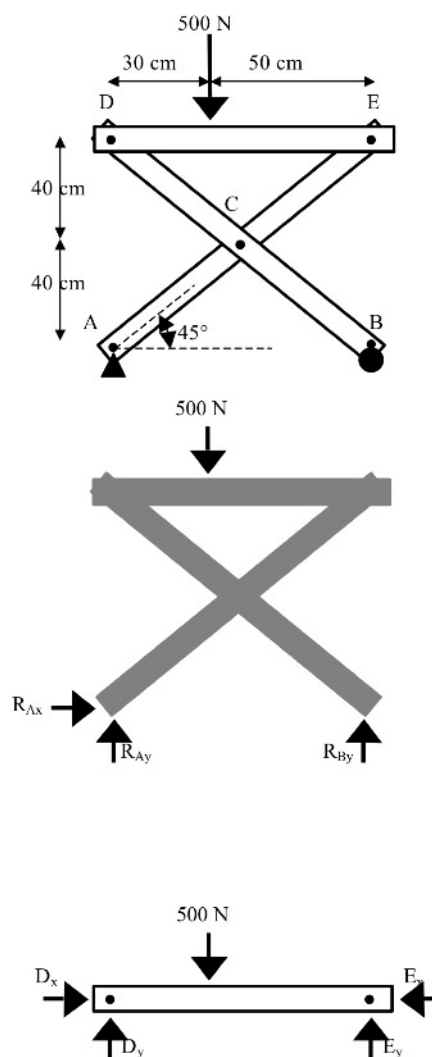
$E_x = D_x$ ...two unknowns, one equation. Solve for these later, using a different frame member.

$$\Sigma M_D = 0 = -500\text{N} \times 30\text{cm} + E_y \times 80\text{cm}$$

$$E_y = (500\text{N} \times 30\text{cm}) / 80\text{cm} = 187\frac{1}{2}\text{N}$$

$$\Sigma F_y = 0 = D_y + E_y - 500\text{N}$$

$$D_y = -E_y + 500\text{N} = -187\frac{1}{2}\text{N} + 500\text{N} = 312\frac{1}{2}\text{N}$$



**Fig. 8:** The first page of the Frame Analysis handout introduces the problem statement, shows how to find the reaction forces, and introduces analysis of one frame member.

The diagram on the second page illustrates how to analyze pin forces on a second frame member. The text at the left explains why the force vectors appear in the opposite direction to the previous figure. Finally, pin forces are calculated and listed in a table for comparison. The text explains the practical purpose for calculating loads on frame pins: namely, to select pins of the right shear strength and diameter.

Continue with **Step 2** for the remaining frame members, until all pin reactions are found.

Notice that the forces on pin D are drawn in the opposite direction to their orientation on the previous member. In static equilibrium, forces applied by one member of the frame onto a pin must be equal and opposite to the forces applied by another member of the frame onto that pin (otherwise the structure will start to move).

$$\Sigma M_C = 0 = D_y \times 40\text{cm} + D_x \times 40\text{cm} + R_{By} \times 40\text{cm}$$

$$0 = D_y + D_x + R_{By}$$

$D_x = -D_y - R_{By} = -312\frac{1}{2}\text{N} - 187\frac{1}{2}\text{N} = -500\text{N}$ , therefore the arrowhead is drawn the wrong way.

$$\Sigma F_x = 0 = C_x + D_x$$

$$C_x = -D_x = -(-500\text{N}) = 500\text{N}$$

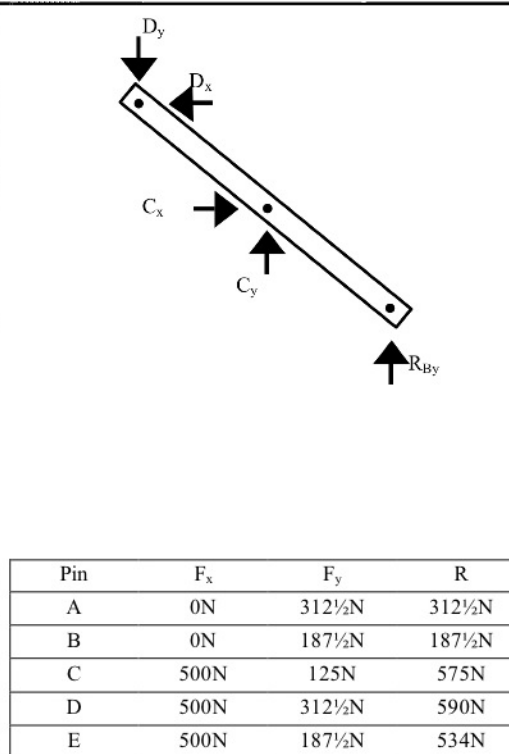
$$\Sigma F_y = 0 = -D_y + C_y + R_{By}$$

$$C_y = D_y - R_{By} = 312\frac{1}{2}\text{N} - 187\frac{1}{2}\text{N} = 125\text{N}$$

Going back to the horizontal member,

$$E_x = D_x = 500\text{N}$$

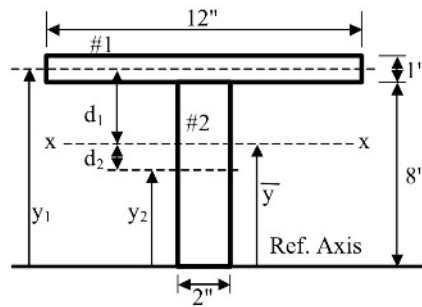
**Step 3** Enter the pin forces into a table, and calculate the resultant force on each pin per  $R = \sqrt{F_x^2 + F_y^2}$ . If you were building a frame, you would use these results to select pins. Instead of using the strongest pin at every joint, you can save money and size the pins according to the load they must carry. For example, the pin used at joint B can be one third as strong as the pin required for joint D.



**Fig. 9:** The second page of the Frame Analysis handout continues with a free-body diagram of a second member, and tabulation of the final results.

## IV. Example #3: Moment of Inertia of a Compound Shape

In my Strength of Materials course, no solution method produces more numerical errors than calculating the moment of inertia of an asymmetric compound shape. Perhaps the reason is there are more steps in this solution method than any other method in the course. Calculating the moment of inertia of this T-shaped section with respect to the x-x centroidal axis is a ten-step process, and an early error inevitably produces an erroneous result. The diagram in a textbook or in a student's notes is similar to Figure 2 or Figure 8, with all calculated dimensions shown. A careful student will have a ten-step mathematical list to follow in solving the problem. However, the order of calculation is not immediately obvious from the diagram, so a less-careful student may struggle to solve the problem.



**Fig. 10:** Diagram for calculating the moment of inertia of a T-shaped section with respect to the x-x centroidal axis, as it might appear in a student's notes or in a textbook.

The handout for Moment of Inertia uses six diagrams which evolve during the problem-solving process. Numerical results are shown in a series of tables which also build as the solution progresses.

### Calculating Moment of Inertia of a Complex Shape

You can calculate the moment of inertia with respect to the y-y axis ( $I_y$ ) of this complex shape by breaking it up into two rectangles...a horizontal one on top, and a vertical one below. Since the y-y centroidal axes of the complex shape and both of its components coincide, you can calculate the moment of inertia of each component with respect to the y-y axis, then add the results.

Calculating  $I_x$  is a little more involved because the shape is not symmetrical about the x-x axis. However, since the complex shape is a combination of simple shapes, you can still calculate  $I_x$ , using the following ten steps.

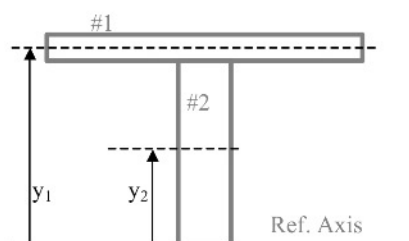
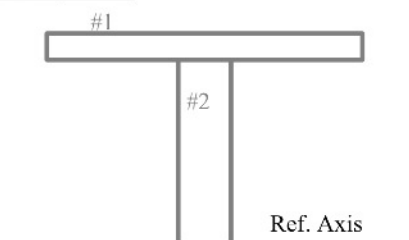
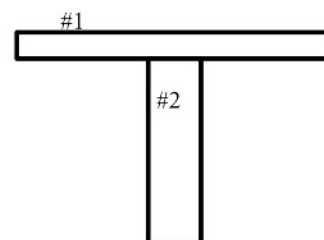
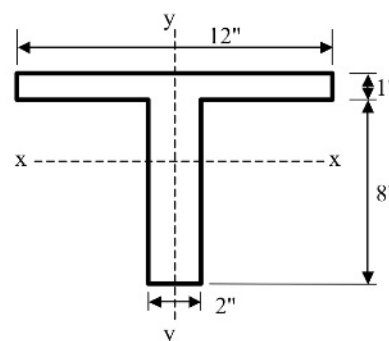
**Step 1** Separate the complex shape into simple shapes, and label the component areas. This complex shape can be split into two rectangles, but this method also works for complex shapes made up of many simple shapes.

**Step 2** Calculate the area (a) of each component. Enter the areas and their sum into a table. Be sure to list the units, because in some problems, you may need to use conversion factors in the calculation.

Part	a (in <sup>2</sup> )
1	12
2	16
Sum	28

**Step 3** Pick a Reference Axis, and label it on the diagram. In theory, you can select any axis, but in practice, the math is usually easier if you pick an axis along the top or bottom of the complex shape (left or right for calculating  $I_y$ ), or along the centroidal axis of one of the component areas.

**Step 4** Draw the distance from the Reference Axis to the centroidal axis of each area. Label these distances  $y_1$ ,  $y_2$ , etc.



**Fig. 11:** The first page of the Moment of Inertia handout starts by introducing the problem, and uses a series of diagrams to show the progression of the solution. Black lines show the current step; gray lines indicate previous steps.

Enter these results into the table.

Part	a (in <sup>2</sup> )	y (in.)
1	12	8.5
2	16	4
Sum	28	

**Step 5** Calculate the value of  $ay$  for each component area. Enter these values and their sum into the table.

Part	a (in <sup>2</sup> )	y (in.)	ay (in. <sup>3</sup> )
1	12	8.5	102
2	16	4	64
Sum	28		166

**Step 6** Draw the distance from the Reference Axis to the x-x centroidal axis of the complex shape.

Calculate this distance as  $\bar{y} = \frac{\Sigma ay}{\Sigma a} = \frac{166 \text{ in.}^3}{28 \text{ in.}^2} = 5.93 \text{ in.}$

**Step 7** Draw the Transfer Distance (d) for each area. This is the distance from the centroidal axis of the area to the centroidal axis of the complex shape.

Enter the results into the table.

Part	a (in. <sup>2</sup> )	y (in.)	ay (in. <sup>3</sup> )	d (in.)
1	12	8.5	102	2.57
2	16	4	64	1.93
Sum	28		166	

**Step 8** Calculate  $I$  for each component area about its centroidal axis. For rectangles,  $I_o = (b h^3)/12$ , where  $b$  is the width of the base, and  $h$  is the height. For other simple shapes,  $I_o$  formulas are listed in the inside back cover of the textbook. Enter these values and their sum into the table.

Part	a (in. <sup>2</sup> )	y (in.)	ay (in. <sup>3</sup> )	d (in.)	$I_o$ (in. <sup>4</sup> )
1	12	8.5	102	2.57	1
2	16	4	64	1.93	85.3
Sum	28		166		86.3

**Step 9** Calculate  $ad^2$  for each component area. Enter these results and their sum into the table.

Part	a (in. <sup>2</sup> )	y (in.)	ay (in. <sup>3</sup> )	d (in.)	$I_o$ (in. <sup>4</sup> )	$ad^2$ (in. <sup>4</sup> )
1	12	8.5	102	2.57	1	79.3
2	16	4	64	1.93	85.3	59.5
Sum	28		166		86.3	139

**Step 10** Use the Transfer Formula to calculate  $I$  for the complex shape.

Note: if a complex shape is not symmetrical about the y-y axis, you can use this 10-step method to find  $I_y$  using a vertical Reference Axis.

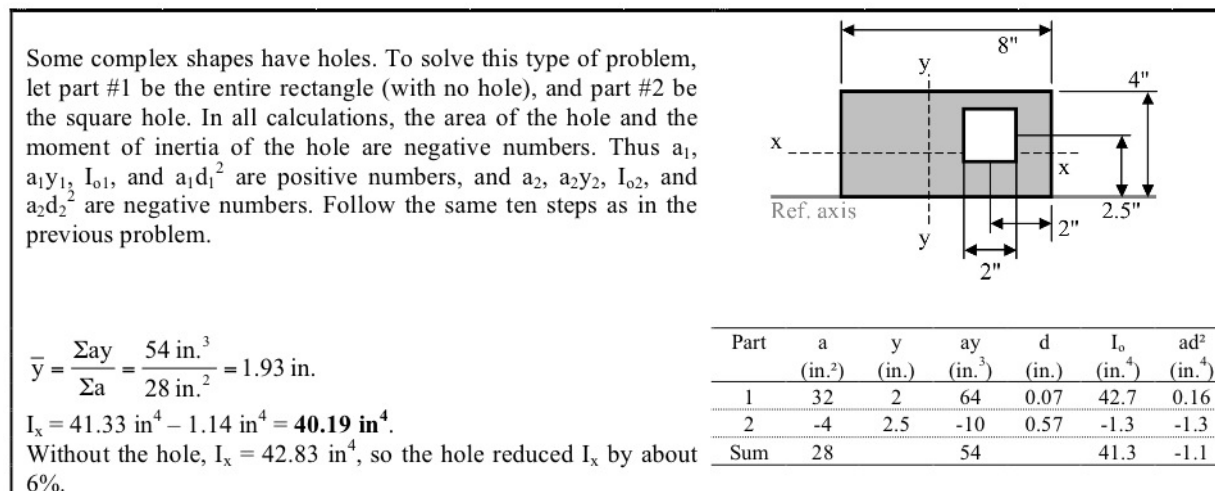
$$I = \Sigma(I_o + ad^2) = \Sigma I_o + \Sigma(ad^2)$$

$$= 86.3 \text{ in}^4 + 138.9 \text{ in}^4 = \mathbf{225.2 \text{ in}^4}.$$

**Fig. 12:** The second page of the Moment of Inertia handout shows how the diagram and table changes as the solution develops.

Each diagram in the Moment of Inertia handout shows a shadow of the previous diagram in gray, with new additions in black, so students can

visualize the problem-solving sequence. Since this method includes a tabular solution, the table evolves with the diagram. An additional diagram explains how to calculate the moment of inertia of a section which has one or more holes.



**Fig. 13:** Moment of Inertia of a compound shape with a hole. The solution includes only one figure and a completed table, similar to a classic textbook presentation

## V. Discussion

Examples 1 through 3 illustrate a method for designing problem-solving handouts so that students can visualize the intermediate steps in a multistep solution. The first two examples show intermediate steps as distinct diagrams, while in example #3, the steps consist of a “build sequence” of a single diagram and a data table. The diagram becomes more complex as construction lines, dimensions, and values are added. If this build sequence were done on a website, changes would best be shown in color, provided the color contrasts are selected to be visible to colorblind students. Gray tones and black were used for the classroom handouts to reduce printing costs. In the first two examples, shading obliterates parts of the diagrams which are irrelevant to the solution. Atherton [6] remarks that “relevant graphics are useful” in class handouts. In problem-solving handouts, relevant graphics are *essential*.



I developed this approach to handout design in my second semester of teaching, so the “controls” in this experiment were six Strength of Materials students learning from a novice college professor, in my first semester of teaching. Classes using this approach have only one section per semester, because I teach at a branch campus with lower enrollment than the main campus. As a consequence, formal assessment of improvements in student learning is not practical. However, anecdotal evidence suggests that students view these handouts as useful tools for solving homework assignments and open-book exam problems. Towards the middle of one semester, students asked for additional problem-solving handouts on new topics.

The field of Mechanics instruction is evolving, with distance learning, [7] experiential learning, [8] and simulation software [9, 10] supplementing and supplanting traditional teaching approaches. Problem-solving handouts are supplements, not substitutes, for textbooks and classroom lecture presentations. It is not practical to include this content in textbooks because of space considerations. However, a large number of problem-solving guides could be stored on websites maintained by professors, textbook authors, or textbook publishers. For example, each frame in a sequential problem-solving technique can appear as a separate webpage. Once the student solves step one, she can click to the next page to solve step two, and so forth.

## VI. Conclusions

Students report that problem-solving handouts help them solve homework and exam problems in Mechanics courses. These handouts help clarify the textbook and lecture notes when the student is solving homework problems away from campus. Some instructors provide handouts of detailed problem solutions *after* students have attempted to solve the problems; the handouts help students correct their errors. In contrast, the problem-solving handouts described here help the students solve problems *before* they submit homework for grading. This approach involves learning, not after-the-fact error correction.



In recent semesters, I have invited students to critique the handouts and recommend improvements, for extra credit points. The experience of editing other people's work will help the students in their future careers in engineering and management.

Many disciplines can benefit from this approach to handout design. For example, other multistep engineering problem-solving methods that trip up students range from applying Kirchoff's Law to an electrical circuit, to applying Bernoulli's Equation in a fluid power circuit. Beyond engineering, this approach can be applied to any multistep process involving visual components, such as the procedure for adding error bars to an x-y graph in a spreadsheet computer program. The greatest benefit of these handouts may arise after graduation, when the engineer attempts to solve a similar problem at work, several years after completing the relevant course.

## References

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- [3] Hibbeler, R.C., *Statics and Mechanics of Materials*, 2<sup>nd</sup> ed. p. 300, 2004.
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- [6] Atherton, J.S., *Learning and Teaching: Handouts* [on-line] accessed 1 March 2005, [www.dmu.ac.uk/~jamesa/teaching/handouts.htm](http://www.dmu.ac.uk/~jamesa/teaching/handouts.htm).

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- [10] *West Point Bridge Designer 2005*, available from The U.S. Military Academy at West Point.

## Appendix

The five frames of the Method of Sections handout appears below in handout form.

### Method of Sections

The Method of Joints is the best way to calculate the tensile or compressive forces in every member of a truss. However, if you only need the forces in a few members, the Method of Sections will save you time.

**Problem** Find the forces in members ID and CD.

**Step 1** Calculate reaction forces at the supports, using three equations:  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$ . Treat the truss as a solid body, since reaction forces depend only on external forces and dimensions.

$$\Sigma M_A = 0 = -3\text{ft.}(100\text{lb.}) - 4\text{ft.}(200\text{lb.}) - 8\text{ft.}(500\text{lb.}) - 16\text{ft.}(80\text{lb.}) + 20\text{ft.}R_{Fy}$$

$$R_{Fy} = \frac{3\text{ft.}(100\text{lb.}) + 4\text{ft.}(200\text{lb.}) + 8\text{ft.}(500\text{lb.}) + 16\text{ft.}(80\text{lb.})}{16\text{ft.}} = 398.75\text{lb.}$$

$$\Sigma F_y = 0 = R_{Ay} + R_{Fy} - 200\text{lb.} - 500\text{lb.} - 80\text{lb.}$$

$$R_{Ay} = -398.75\text{lb.} + 200\text{lb.} + 500\text{lb.} + 80\text{lb.} = 381.25\text{lb.}$$

$$\Sigma F_x = 0 = 100\text{lb.} + R_{Ax}$$

$$R_{Ax} = -100\text{lb.}$$

Since  $R_{Ax}$  is negative, the arrow is drawn backwards. Leave the arrow in this direction in all subsequent diagrams, and use the value of  $-100\text{lb.}$

**Step 2** Cut the truss. The cut must pass through a member you are solving for. The cut does not have to be vertical, or even straight, but it should pass through the fewest possible members. In this problem, a single cut passes through members ID and CD. In some problems, you may need to make more than one cut to calculate all the required forces.

**Step 3** Draw one portion of the cut truss. Draw cut members as if they were external forces acting on the cut portion.

**Step 4** Use  $\Sigma M=0$ ,  $\Sigma F_x=0$ , and  $\Sigma F_y=0$  to calculate the forces in the cut members.

$$\Sigma M_I = 0 = 3\text{ft.}CD + 4\text{ft.}(200\text{lb.}) + 3\text{ft.}R_{Ax} - 8\text{ft.}R_{Ay}$$

$$CD = \frac{-4\text{ft.}(200\text{lb.}) - 3\text{ft.}(-100\text{lb.}) + 8\text{ft.}(381.25\text{lb.})}{3\text{ft.}} = 850\text{lb.}$$

CD is positive, so the arrow is drawn correctly.  $CD = 850\text{lb.}$  tension.

The vertical component of ID is  $(3/\sqrt{13})ID$ .

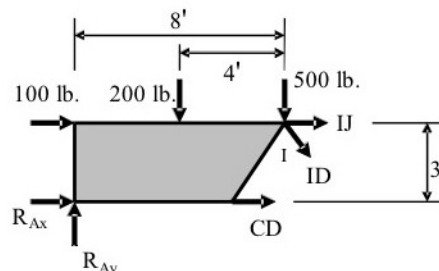
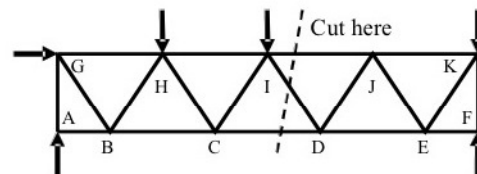
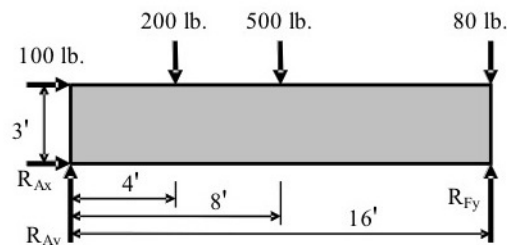
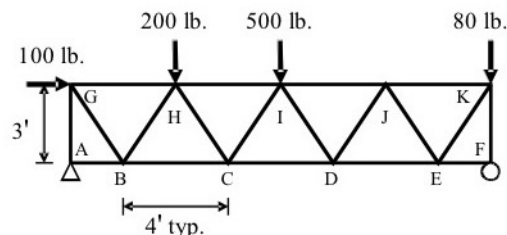
$$\Sigma F_y = 0 = R_{Ay} - 200\text{lb.} - 500\text{lb.} - (3/\sqrt{13})ID$$

$$ID = \frac{381.25\text{lb.} - 200\text{lb.} - 500\text{lb.}}{3/\sqrt{13}} = -383.09\text{lb.}$$

ID is negative, so the arrow is drawn backwards.

$ID = 383.09\text{ lb.}$  compression.

**Alternate Solution** Use the other portion of the cut truss. This solution looks simpler...instead of three applied loads and two reaction forces, there is only one applied load and one reaction force. Use  $\Sigma F_y=0$  to find ID, then use  $\Sigma M_J=0$  to find CD.



$$3' \triangle \sqrt{(3')^2 + (2')^2} = \sqrt{13} \text{ ft.}$$

